

Claims

[c1] What is claimed is:

1. A trench capacitor having a large capacitor surface area, comprising:
 - a buried diffusion plate doped in a substrate and encompassing a bottle-shaped lower portion of said trench capacitor, said buried diffusion plate being electrically connected to an upwardly extending cylindrical center electrode via a bottom contact surface of said bottle-shaped lower portion, wherein said buried diffusion plate and said upwardly extending cylindrical center electrode serve as a first electrode of said trench capacitor;
 - a first insulation layer disposed on interior surface of said bottle-shaped lower portion of said trench capacitor except for said bottom contact surface;
 - an outer electrode layer situated on said first insulation layer and encircling said cylindrical center electrode;
 - a second insulation layer disposed between said outer electrode layer and said cylindrical center electrode;
 - a central pillar electrode downwardly extending along the length of said cylindrical center electrode and encompassed by said cylindrical center electrode;
 - a third insulation layer disposed between said central

pillar electrode and said cylindrical center electrode; and a collar electrode layer located on said central pillar electrode and on said outer electrode layer, said collar electrode layer being electrically connected to said central pillar electrode and said outer electrode layer, wherein said collar electrode layer, said central pillar electrode and said outer electrode layer constitute a second electrode of said trench capacitor.

- [c2] 2. The trench capacitor according to claim 1 wherein said cylindrical center electrode upwardly extends along the length of said bottle-shaped lower portion of said trench capacitor.
- [c3] 3. The trench capacitor according to claim 1 wherein said trench capacitor further comprises a capacitor neck portion above said bottle-shaped lower portion of said trench capacitor.
- [c4] 4. The trench capacitor according to claim 3 wherein said trench capacitor further comprises a collar oxide layer situated on sidewall of said capacitor neck portion.
- [c5] 5. The trench capacitor according to claim 1 wherein said buried diffusion plate is covered by a metal layer, and said buried diffusion plate and said metal layer serving as the first electrode of said trench capacitor.

- [c6] 6. The trench capacitor according to claim 1 wherein said buried diffusion plate is an N⁺ diffusion plate.
- [c7] 7. The trench capacitor according to claim 6 wherein said N⁺ diffusion plate is doped by Gas Phase Doping (GPD) method.
- [c8] 8. The trench capacitor according to claim 6 wherein said N⁺ diffusion plate is doped by Arsenic-doped Silicate Glass (ASG).
- [c9] 9. The trench capacitor according to claim 1 wherein said cylindrical center electrode is made of polysilicon or metals.
- [c10] 10. The trench capacitor according to claim 1 wherein said collar electrode layer, said central pillar electrode and said outer electrode layer are made of polysilicon or metals.
- [c11] 11. The trench capacitor according to claim 1 wherein said first insulation layer is made of dielectric material selected from the group consisting of silicon nitride, oxynitride, ONO, NO, Al₂O₃, HfO₂, Ta₂O₅, ZrO₂, and (Al₂O₃)_x(HfO₂)_y.
- [c12] 12. The trench capacitor according to claim 1 wherein said the second insulation layer comprises silicon oxide,

Al_2O_3 , HfO_2 , and any suitable dielectric films.

- [c13] 13. The trench capacitor according to claim 11 wherein said the second insulation layer is a thermally formed silicon dioxide layer.
- [c14] 14. The trench capacitor according to claim 11 wherein said the second insulation layer is deposited by atomic layer deposition (ALD) method.
- [c15] 15. The trench capacitor according to claim 11 wherein said the second insulation layer is deposited by chemical vapor deposition (CVD) method.
- [c16] 16. The trench capacitor according to claim 1 wherein said third insulation layer is made of dielectric material selected from the group consisting of silicon nitride, oxynitride, ONO, NO, Al_2O_3 , HfO_2 , Ta_2O_5 , ZrO_2 , and $(\text{Al}_2\text{O}_3)_x/(\text{HfO}_2)_y$.
- [c17] 17. A trench capacitor, comprising:
 - a first electrode embedded in a deep trench and comprising a collar electrode layer, a central pillar electrode and an outer electrode layer;
 - a second electrode isolated from said first electrode by at least one dielectric film, said second electrode comprising a bottom electrode in a substrate and an upwardly extending cylindrical center electrode electrically

connected to said buried diffusion plate via a bottom contact surface of a bottle-shaped lower portion of said deep trench, wherein said buried diffusion plate encompasses said bottle-shaped lower portion of said deep trench.

- [c18] 18. The trench capacitor according to claim 17 wherein said deep trench further comprises a neck channel above said bottle-shaped lower portion and said collar electrode layer is embedded in said neck channel.
- [c19] 19. The trench capacitor according to claim 17 wherein said central pillar electrode and said outer electrode layer are formed within said bottle-shaped lower portion of said deep trench.
- [c20] 20. The trench capacitor according to claim 17 wherein said outer electrode layer encircles said upwardly extending cylindrical center electrode of said second electrode, and said upwardly extending cylindrical center electrode of said second electrode encircles said central pillar electrode of said first electrode.
- [c21] 21. The trench capacitor according to claim 17 wherein said collar electrode layer is electrically connected to said central pillar electrode and said outer electrode layer.

- [c22] 22. The trench capacitor according to claim 17 wherein said bottom electrode comprises a buried diffusion layer.
- [c23] 23. The trench capacitor according to claim 17 wherein said bottom electrode comprises a buried diffusion layer and a metal layer.